

UNITED STATES PATENT APPLICATION FOR

LIGHT GUIDE SPACERS FOR BACKLIGHTING A REFLECTIVE DISPLAY

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# LIGHT GUIDE SPACERS FOR BACKLIGHTING A REFLECTIVE DISPLAY

## FIELD OF THE INVENTION

5           Embodiments of the present invention relate to the field of portable electronic devices that contain display devices. More particularly, embodiments of the present invention relate to reflective displays which use light guides to conduct light through the display from a backlight device.

## 10       BACKGROUND OF THE INVENTION

          Advances in computer technology have enabled the further miniaturization of the components required to build computer systems. As such, new categories of computer systems have been created. One of the newer  
15       categories of computer systems is the portable, hand held, or "palmtop" computer system, also referred to as a personal digital assistant or PDA. Other examples of a portable computer system include electronic address books, electronic day planners, electronic schedulers and the like.

20           A palmtop computer system is a computer that is small enough to be held in the user's hand and as such is "palm-sized." As a result, palmtops are readily carried about in the user's briefcase, purse, and in some instances, in the user's

pocket. By virtue of its size, the palmtop computer, being inherently lightweight, is therefore exceptionally portable and convenient.

Flat panel reflective displays are frequently used in palmtop computer systems due to their light weight, low cost, and simplicity. Reflective displays do not emit light from an internal source but rely upon reflecting light from another source to illuminate the display. However, reflective displays have disadvantages such as being relatively thick and inefficient due to the need for a front light apparatus to illuminate the display. Figure 1A is a sectional view of an exemplary prior art reflective display assembly in a handheld computer. In Figure 1A, an input assembly 110 is disposed above a light guide 120 which is disposed above a reflective display 130. Light guide 120 uses microstructures 121 on its top surface to reflect light from light sources 140 down onto reflective display 130 to illuminate the display. Light guide 120 is sufficiently transparent that light reflected from reflective display 130 can pass through to allow a user to view the display.

One disadvantage associated with the reflective display assembly of Figure 1A is the fact that light guide 120 has to be transparent in order for reflective display 130 to be visible to a user. Because of this requirement, light guide 120 is not optimized to reflect light onto reflective display 130. This leads to higher power usage to provide enough light to illuminate the display sufficiently. This in turn reduces battery life which is a critical resource for

handheld computers. Furthermore, light distribution is not uniform in that the portions of the reflective display 130 closest to light sources 140 appear brighter than center portions of the display. Light diffusers, which would normally be used to distribute light more uniformly, are not normally used with reflective displays as they would degrade the display quality by interfering with the light reflected from the display surface.

Another disadvantage of reflective displays is the requirement that the input assembly (e.g., input assembly 110 of Figure 1A) be rigid. The microstructures on the top surface of light guide 120 are fragile and damaging them could further reduce their ability to reflect light onto reflective display 130. Therefore a space 122 is maintained between the input assembly and the light guide to protect the microstructures from damage. Furthermore, the microstructures have to maintain a precise alignment relative to light sources 140 in order to channel light onto reflective display 130 as evenly as possible. Because of this requirement, input assembly 110 is usually a thick, rigid, glass assembly which prevents manufacturing a thinner, curved, or flexible display assembly.

Figure 1B is a sectional view of a typical reflective display device such as a liquid crystal display (LCD) utilized in the prior art. A top layer 150 and a bottom layer 160 surround a liquid crystal layer 170 which has seals 180 along

the edges to further contain the liquid crystal. Light is reflected from the top surface 161 of bottom layer 160 back to a viewer.

Many display technologies, such as LCDs, which rely upon a fluid layer  
5 require some sort of structure to maintain distance between the top layer (e.g., top layer 150) and a bottom layer (e.g., bottom layer 160). In Figure 1B, glass balls 190 are used for this purpose. Glass balls 190 maintain the distance between top layer 150 and bottom layer 160 yet are small enough to be indiscernible to a user, particularly when they are in a liquid. Other structures  
10 used for this purpose include columns or pillars extending from the bottom layer to the top layer which keep the layers separate. These columns are usually glass or some sort of semi-conductor material.

## SUMMARY OF THE INVENTION

Accordingly, the need exists for a more efficient reflective display for an electronic device. In particular, a need exists for a reflective display which can  
5 uniformly illuminate a reflective display and uses less power without diminishing the visual quality of the display. While meeting the above stated need, it would be advantageous to provide a reflective display which is thinner, flexible, and permits the use of curved or three dimensional displays for handheld computers.

10 Embodiments of the present invention are directed to a reflective display assembly for an electronic device which utilizes spacers typically found in some reflective display devices as light guides to conduct light from a backlight through the reflective display itself. The light is then reflected back down onto  
15 the top surface of the reflective display by a brightness enhancement film to illuminate the reflective display. Brightness enhancing films disposed above the backlight device can also be utilized to direct more of the available light up through the light guides. The present invention provides efficient, uniform illumination for a reflective display device and embodiments of the present  
20 invention facilitate manufacturing thinner, flexible, and curved or three dimensional displays for handheld computers.

Embodiments of the present invention are directed to a reflective display assembly for an electronic device which is disposed above a backlight device.

A light guide within the reflective display conducts light from the backlight device, through the reflective display, to the top layer of the reflective display.

- 5 The light is then reflected down onto the face of the reflective display by a reflecting film above the display. The reflecting film is sufficiently transparent that a viewer can read the illuminated reflective display.

These and other advantages of the present invention will become  
10 obvious to those of ordinary skill in the art after having read the following detailed description of the preferred embodiments which are illustrated in the various drawing figures.

## BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of this specification, illustrate embodiments of the present invention and, together with the description, serve to explain the principles of the invention.

FIGURE 1A-1B are sectional views of prior art display assemblies.

FIGURE 2 illustrates an exemplary portable computer system upon which embodiments of the present invention may be utilized.

FIGURE 3 is a diagram of an exemplary computer network including a portable computer system utilized in accordance with embodiments of the present invention.

FIGURES 4A and 4B are a sectional view and a top view of a reflective display in accordance with embodiments of the present invention.

FIGURE 5 is a sectional view of a display assembly in accordance with one embodiment of the present invention.

FIGURES 6A and 6B are top and sectional views respectively of an of a reflective display in accordance with one embodiment of the present invention.



FIGURE 7 is a sectional view of a reflective display in accordance with one embodiment of the present invention.

FIG. 7 is a sectional view of a reflective display in accordance with one embodiment of the present invention. The diagram shows a cross-section of a display assembly. At the top, there is a layer labeled 100, which is a substrate. Below this is a layer labeled 110, which is a reflective layer. Underneath the reflective layer is a layer labeled 120, which is a dielectric layer. Below the dielectric layer is a layer labeled 130, which is a conductive layer. At the bottom, there is a layer labeled 140, which is a substrate. The layers are stacked vertically, with the reflective layer 110 being the central layer. The conductive layer 130 is located between the dielectric layer 120 and the bottom substrate 140. The top substrate 100 is above the reflective layer 110. The diagram is a schematic representation of the physical structure of the reflective display.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference will now be made in detail to the preferred embodiments of the present invention, light guide spacers for backlighting a reflective display, examples of which are illustrated in the accompanying drawings. While the present invention will be described in conjunction with the preferred embodiments, it will be understood that they are not intended to limit the present invention to these embodiments. On the contrary, the present invention is intended to cover alternatives, modifications, and equivalents which may be included within the spirit and scope of the present invention as defined by the appended claims. Furthermore, in the following detailed description of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be obvious to one of ordinary skill in the art that the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, components, and circuits have not been described in detail so as not to unnecessarily obscure aspects of the present invention.

Figure 2 illustrates exemplary circuitry of portable computer system 200. Portable computer system 200 includes an address/data bus 201 for communicating information, a central processor 202 coupled with the bus 201 for processing information and instructions, a volatile memory 203 (e.g., random access memory RAM) coupled with the bus 201 for storing information and

instructions for the central processor 202 and a non-volatile memory 204 (e.g., read only memory ROM) coupled with the bus 201 for storing static information and instructions for the processor 202. Portable computer system 200 also includes an optional data storage device 205 (e.g., thin profile removable  
5 memory) coupled with the bus 201 for storing information and instructions and which can be removable.

As described above, portable computer system 200 also contains a signal communication device 206, also coupled to bus 201. Signal  
10 communication device 206 can be a serial port (or USB port) for communicating with a cradle (not shown). In addition to device 206, wireless communication links can be established between the portable computer system 200 and a host computer system (or another portable computer system) using a Bluetooth wireless device 207 or an infrared device 208. These components are housed  
15 on a circuit board 209 which is contained within a cover assembly.

Also included in computer system 200 of Figure 2 is a display device 210. Display device 210 may be an electronic ink, electronic paper, digital paper or other reflective display devices suitable for creating graphic images  
20 and alphanumeric characters recognizable to the user.

Device 200 also includes an alphanumeric input device 211 coupled with bus 201. In the present invention, the input device 211 may include a flat

panel resistive touch screen display as described above. Input device 211 can communicate information (spatial data) and command selections to the central processor 202. Input device 211 is capable of registering a position on the display device 210 where contact is made.

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Figure 3 is a block diagram of an exemplary network environment 300 including a portable computer system (e.g., portable computer system 200) upon which embodiments of the present invention may be practiced, in accordance with one embodiment of the present invention. Portable computer system 200 is also known as a palmtop or palm-sized computer system. In one embodiment, portable computer system 200 has the ability to transmit and receive data and information over a wireless communication interface (e.g., a radio interface). For purposes of the present application, the term "portable computer system" is not intended to be limited solely to conventional palmtop or portable computers. Instead, the term "portable computer" or "portable computer system" is also intended to include any mobile electronic device. Such mobile devices include but are not limited to pagers and paging systems, wireless and cellular telephones, electronic address books, and numerous other mobile devices that may have the ability to conduct wireless communications with a network. As such, for purposes of the present application, the terms "portable computer" and "mobile device" will be considered synonymous and will be used interchangeably.

Base station 310 can be both a transmitter and receiver base station, which can be implemented by coupling it into an existing public switched telephone network 320. Implemented in this manner, base station 310 enables portable computer system 200 to communicate with a proxy server computer system 330, which is coupled by wire to the existing public switched telephone network 320. Furthermore, proxy server computer system 330 is coupled to the Internet 340, thereby enabling portable computer system 200 to communicate with the Internet 340. When communicating with a Web site over Internet 340, protocols such as CTP (Compact Transport Protocol) and CML (Compact Markup Language) and WML (Wireless Markup Language) can be used by portable computer system 200 in the present embodiment.

It should be appreciated that one of the functions of proxy server 330 is to perform operations over the Internet 340 on behalf of portable computer system 200. For example, proxy server 330 has a particular Internet address and acts as a proxy device for portable computer system 200 over the Internet 340. It should be further appreciated that other embodiments of a communications network, planned or envisioned, may be utilized in accordance with the present invention. For example, a wireless connection may be made from portable computer system 200 directly to the Internet 340.

The data and information which are communicated between base station 310 and portable computer system 200 are the same type of information and

data that can conventionally be transferred and received over a public switched telephone network. Additionally, in Figure 3, the existing public switched telephone network could also be a packet-based network utilized by some conventional portable computer systems. However, a wireless communication interface is utilized to communicate data and information between portable computer system 200 and base station 310. Furthermore, nearly any wireless network can support the functionality to be disclosed herein.

Figure 4A is a sectional view of an exemplary reflective display assembly 400 which has a reflective display that utilizes light guide spacer in accordance with embodiments of the present invention. In assembly 400, a backlight device 410 is disposed below an optional brightness enhancement film (BEF) 420 and a reflective display 430. BEF film 420 is used in embodiments of the present invention to more precisely direct light from backlight device 410 into the light guide spacers of the present invention. Microstructures on the bottom of BEF 420 direct light toward the light guide spacers by reflecting light away from areas of reflective display 430 which do not have light guide spacers. This concentrates the greatest amount of available light toward the light guide spacers and in turn creates a brighter reflective display.

In one embodiment, backlight device 410 is an electro-luminescent device. An electro-luminescent device is a phosphor sheet with attached electrodes. When a sinusoidal signal is applied, the entire face of the sheet

lights up. Electro-luminescent backlight devices are very thin and flexible and facilitate, for example, creating a display assembly for an electronic device which has a flexible or curved face. Another advantage to using an electro-luminescent backlight device is that the light is uniformly distributed across the entire surface of the display. In other embodiments of the present invention, backlight device 410 can be, for example, a light emitting diode (LED) device or a cold cathode fluorescent tube (CCFT) backlight device.

Reflective display 430 is further comprised of bottom sheet 431 having a top surface 432, light guide spacers 433, sub-pixel areas 434, a top sheet 435 having a top surface 436, and seals 437. In one embodiment top surface 432 is a reflective layer which reflects light back through top sheet 435. In one embodiment, bottom sheet 431 and top sheet 435 are a transparent plastic material such as PET plastic which are flexible and allow light to pass through it. When used in conjunction with a flexible electro-luminescent backlight (e.g., backlight device 410 ) reflective display assembly 400 can be a flexible, backlighted, reflective display. Light guide spacers 433 extend through the reflective material of top surface 432 and conduct light from backlight device 410 which passes through bottom sheet 431 to top sheet 435 which is transparent enough for the light to pass through top surface 436. Light guide spacers 433 are arranged to around an area of reflective display 430 such as a pixel or sub-pixel area by, for example, placing light guide spacers in the corners of areas between sub-pixels as shown in Figure 4B in which light guide

spacers 433 surround sub-pixel areas 434. In one embodiment, seals 437 are able to conduct light as well.

Light which passes through top sheet 435 reflects off of microstructures  
5 on the bottom of a front light reflecting film 440 which has the characteristics of a  
dual brightness enhancement film (DBEF). DBEF layers are used to recycle  
light in display devices by, for example, reflecting light which does not pass  
through a polarizing layer. In one embodiment of the present invention, front  
light reflecting film 440 has reflective pyramid shaped microstructures 441  
10 which reflect light that is conducted by light guide spacers 433 back down onto  
reflective display 430. However, front light reflecting film 440 is sufficiently  
transparent to allow a user to view reflective display 430. This facilitates a more  
uniform distribution of light across reflective display 430. Front light reflecting  
film 440 has a mesh structure and the pitch of reflective microstructures 441 is  
15 aligned with light guide spacers 433 to efficiently reflect light onto reflective  
display 430 without diminishing the display quality.

Figure 5 is a sectional view of an exemplary reflective display 500 for an  
electronic device which uses light guide spacers in accordance with  
20 embodiments of the present invention. Reflective display 500 is an electronic  
ink display which uses charged, colored particles to create images. In Figure 5,  
microcapsules 510 are disposed between a top layer 520 and a bottom layer  
530.



In one embodiment, microcapsules 510 contain positively charged white particles 540 and negatively charged black particles 550 which are suspended in a clear fluid or, in another embodiment, are suspended in a black ink. In

5 another embodiment, colored particles (e.g., red, green, and blue) or color filers are used so that a color display is possible rather than monochrome. When a negative electric field is applied to top layer 520, positively charged white particles 540 are attracted to top layer 520 and move to the top of microcapsule 510 to become visible to a user, thus making the surface appear white at that  
10 portion of display 500. At the same time, an opposite electric field pulls black particles 550 toward bottom layer 530 of display 500 where they are hidden. By reversing this process and applying a positive electric field to top layer 520, as shown in Figure 5, the black particles now appear at the top of microcapsule 510, which now makes that portion of display 500 appear dark, while the white  
15 particles are pulled to the bottom of microcapsule 510.

In one embodiment, top layer 520 and bottom layer 530 are clear electrodes. In another embodiment, electronic ink microcapsules 510 are disposed between two clear, flexible plastic layers (e.g., top layer 520 and  
20 bottom layer 530) to create an electronic paper display. Electronic paper has advantages over conventional display devices used in handheld computers because it is thin and flexible. Because it can hold an image when power is no longer supplied, it requires substantially less power than other display

technologies. This is a critical issue for handheld electronic devices which have limited battery life.

In the present invention, reflective display 500 is further comprised of a light guide spacer 560 which conducts light from a backlight device (e.g., backlight device 410 of Figure 4A) which has passed through bottom layer 530 to top layer 520. The light is then reflected back onto reflective display 500 by a front light reflecting film (e.g., front light reflecting film 440 of Figure 4A) as previously described.

Figures 6A and 6B are top and sectional views respectively of an exemplary electronic paper display 600 which uses light guide spacers in accordance with embodiments of the present invention. Figure 6A shows a top view of electronic paper display 600 showing a plurality of enclosures 610 which, in one embodiment, are embossed into a substrate 620 using micro-embossing techniques. In one embodiment, enclosures 610 are sub-pixel areas of electronic paper display 600. However, enclosures 610 can, in another embodiment, contain multiple sub-pixels to define a pixel of display 600.

Enclosures 610 hold a plurality of particles 630 which, for example are white on one side and black on another side. Particles 630 have a polarity such that, in one embodiment, the black portion of the particle is negatively charged

while the white portion of the particle is positively charged. Particles 630 are suspended in a liquid and held in enclosures 610 by a transparent top layer 640. When a negative electric field is applied to top layer 640 the positive portions of are attracted to the electric field. This causes particles 630 to rotate  
5 in the liquid such that the white portions of particles 630 are facing top layer 640 and makes reflective display appear to be white at that portion of the display. When a positive electric field is applied to top layer 640, the negatively charged black portion of particle 630 is attracted to top layer 640 and reflective display 600 appears to be black in that area.

10 In one embodiment of the present invention, substrate 620 is a transparent layer, such as a mylar sheet, which can conduct light from a backlight device (e.g., backlight device 210 of Figure 2) to top layer 640. In so doing, substrate 620 acts as the light guide spacer for electronic paper display  
15 600. The conducted light is then reflected back onto display 600 by a front light reflecting film (e.g., front light reflecting film 440 of Figure 4). An advantage of display 600 is that light is conducted uniformly over a greater surface area of the display which results in a brighter, clearer display.

20 In another embodiment of the present invention, enclosures 610 contain microcapsules (e.g., microcapsules 510 of Figure 5) containing charged, colored particles (e.g., white particles 540 and black particles 550 of Figure 5). When a positive electrical current is applied to top layer 640, the negatively

charged particles (e.g., black particles 550 of Figure 5) within the microcapsules are attracted to top sheet 640 and reflective display 600 appears dark in that region.

5           Figure 7 is a top view of an exemplary digital paper display 700 utilizing micro-machining technology and light guide spacers in accordance with embodiments of the present invention. Digital paper display 700 can be used as a reflective display (e.g., reflective display 430 of Figure 4A) for an electronic device. In Figure 7, a plurality of thin, flexible, aluminum strips 710 are  
10       disposed across the surface of the display. The ends of aluminum strips 710 are coupled with electrical traces for carrying electrical current away from the aluminum strips to complete an electrical circuit. A plurality of electrodes 720 are disposed beneath aluminum strips 710. In one embodiment, electrodes 720 are Indium Tin Oxide (ITO) electrodes. The intersection where aluminum  
15       strips 710 overlies electrodes 720 defines a pixel area 730.

          An electrical current is applied to a selected electrode and is conducted away via a selected strip of aluminum through one of the defined pixel areas 730. As current passes through pixel area 730, it causes the aluminum strip in  
20       the region of pixel area 730 to deflect. In so doing, the reflective property of the pixel area is changed and light is now reflected back to a viewer at a different wavelength. By altering the current passing through the electrodes, the amount of deflection in the pixel areas can be controlled to create a spectrum of colors.

In the present invention, light guide spacers 740 are inserted into the corner areas between the pixels. This is easily accomplished because small gaps are necessary between the individual aluminum strips 710 and the individual electrodes 720 as shown in Figure 7. In another embodiment, small portions of the corners of the pixel areas are removed to accommodate larger light guide spacers. When used in conjunction with a backlight device (e.g., backlight device 410 of Figure 4A), light is conducted by light guide spacers 740 and is reflected onto reflective display 700 by a front light reflecting film (e.g., front light reflecting film 440 of Figure 4A) as previously described.

The preferred embodiment of the present invention, light guide spacers for backlighting a reflective display, is thus described. While the present invention has been described in particular embodiments, it should be appreciated that the present invention should not be construed as limited by such embodiments, but rather construed according to the following claims.